SCIENCE

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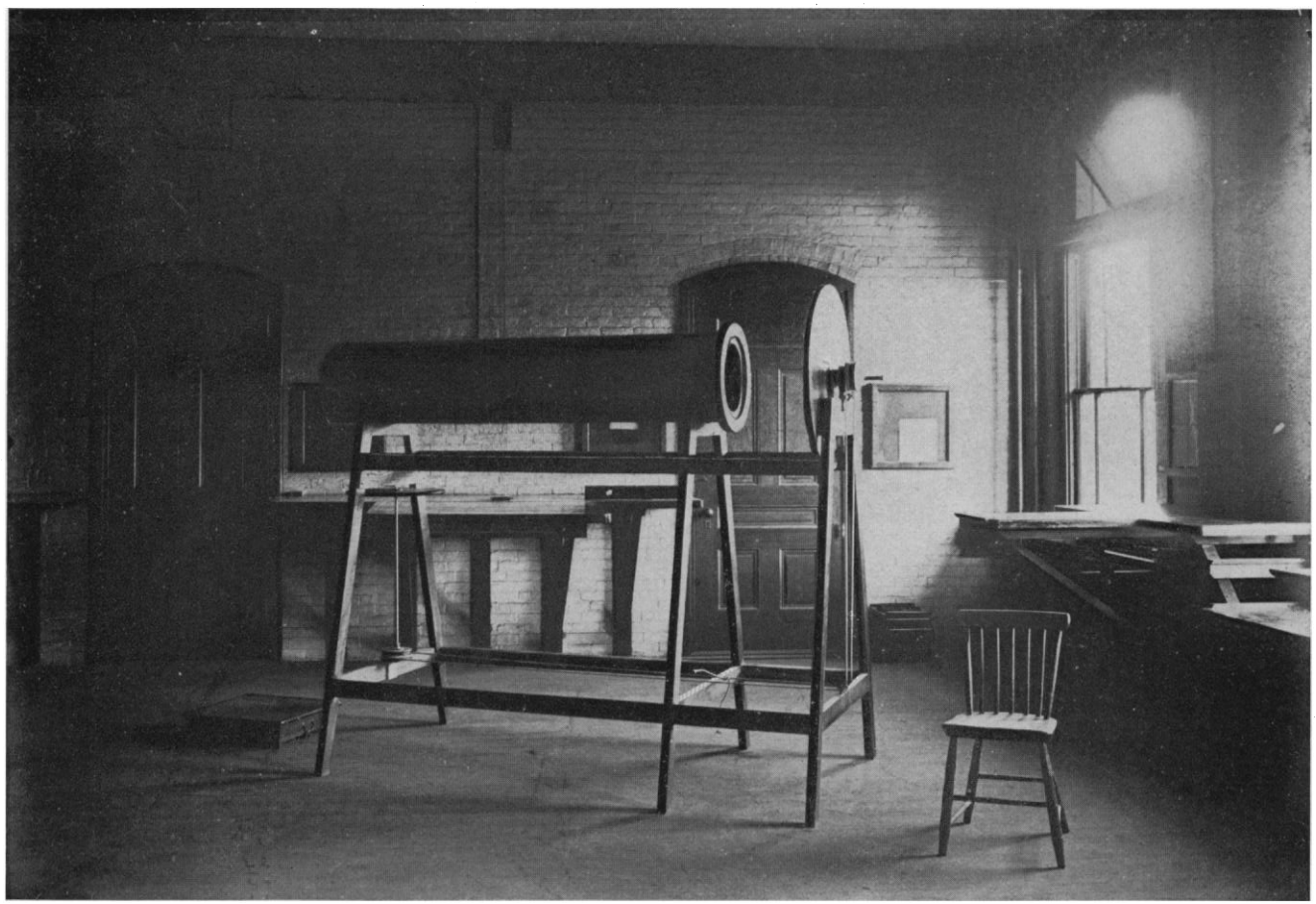
MSS. intended for publication and books, etc., intended for review should be sent to the responsible editor, Professor J. McKeen Cattell, Garrison-on-Hudson, N. Y.

THE PERCEPTION OF HORIZONTAL AND OF VERTICAL LINES.

ALMOST every person is occasionally called on to decide 'by the eye' whether some straight line is horizontal or some other line vertical. It usually happens, as, for instance, when one has to set a picture straight on the wall of a room, that the judgment is helped by the presence, in the neighborhood, of other lines, known to be nearly horizontal or vertical, but sometimes all standards are lacking and then the decision is a little more difficult to make.

In order to find out whether such training as a student of physics gets from several years of laboratory work is likely to improve his judgment in such matters as these, and whether astigmatism affects the results materially, I have experimented in the Jefferson Physical Laboratory upon forty persons who kindly consented to make observations for me.

We used two very simple pieces of apparatus. One of these is a fixed horizontal telescope, the eye piece of which can turn freely in its tube. The eye piece carries a single cross hair within, and a large sheet brass disc coaxial with the telescope without. This disc serves as an eye screen, and carries, on the side away from the observer, a divided circle which has a fixed reading microscope. The observer, sitting in a chair before the instrument, with eyes screened from a view of extraneous objects, turns the disc while



PEIRCE ON THE PERCEPTION OF HORIZONTAL AND OF VERTICAL LINES.

looking through the telescope with one eye, until the cross hair, which turns with the disc, seems to be vertical, or horizontal, as the case may be. A piece of ground glass in front of the object glass allows light to have access to the inside of the telescope, but keeps out all disturbing images. An assistant then reads off on the scale, and records, the deviation from verticality or horizontality, and a new setting is made. The mean of a dozen settings, ranging in the cases of some persons over as much as two degrees, suffices to show whether the observer has a decided bias and to measure it fairly well, if it exists. The subjoined table (I) gives the results of the observations of ten persons, five of whom are instructors in Harvard University. The last observer in the list is a lady. The first two and the seventh observers are astigmatic. The first two columns give in degrees the means of the deviations from level of a number of horizontal settings of the cross hair made with the left eye and the right eye respectively. The next two columns give corresponding means of vertical settings. In all the cases the positive sign implies a rotation from the correct position in clockwise direction. The horizontal determinations of all the observers except one, illustrate a fact, familiar to some astronomers and physicists, that a cross hair which seems level to the right eye of a person generally needs to be rotated slightly in counter-clockwise direction to suit the left eye. The third line of the third column shows the only large bias that I have found. In a large number of cases, as the table shows, the deviation of the mean was practically nothing. When the ground glass in front of the object glass was removed, a plumb line made of silk fibre appeared in the field of the telescope, and many settings have been made, by different persons who have used this apparatus, which could not be in the least improved when the plumb line became visible. Observations made by the same person on different days show slight differences in general, but unusual fatigue sometimes introduces a temporary bias of half a degree or perhaps a little more. I have not been able to discover from settings made with unscreened eyes in a room in which many horizontal and vertical lines may be seen, that observers are much affected by after images, or by outside standards not nearly superposed upon the line to be set, provided that the head is erect.

Table I.

Observer.	Mean deviation of horizontal settings made with		Mean deviation of vertical settings made with	
	the left eye.	the right eye.	the left eye.	the righ eye.
1	+0°.6	+1°.2	−2°.3	+0°.2
2	+0 .1	−0 .9	−0 .2	−1 .4
3	−1 .5	+0 .8	−5 .2	−0 .5
4	−0 .2	+0 .6	±0 .0	+0 .6
5	+0 .1	+0 .8	±0 .0	+0 .8
6	−0 .6	+0 .6	−0 .2	+0 .1
7	−0 .1	+0 .8	+0 .4	+0 .5
8	−0 .2	+0 .7	−0 .2	−0 .1
9	±0 .0	+0 .4	−0 .2	−0 .3
10	−0 .7	±0 .0	±0 .0	±0 .0

To find out whether the accuracy of the results depended mainly upon the horizontality of the seat occupied by the observer, a long series of settings were made by a person who sat in a chair which rested upon a platform inclined about 5°, first towards the left and then towards the right. The feet of the observer were placed upon the rungs of the chair. The exact agreement of the deviations, as shown in the following table (II) is, of course, accidental, but it is clear that the inclination of the seat did not appreciably affect the judgment of this person.

Table II.

Seat inclined to the left.				Seat inclined to the right.			
Horizontal settings.		Vertical settings.		Horizontal settings.		Vertical settings.	
Left eye.	Right eye.	Left eye.	Right eye.	Left eye.	Right eye.	Left eye.	Right eye.
−0°.3	+0°.7	+0°.5	+0°.7	−0°.3	+0°.7	+0°.5	+0°.7

If, while a person is sittting or standing, the head be much inclined, the deviations of the settings of the cross hair become much greater than when the head is erect. The apparently horizontal and the apparently vertical lines seem always to be turned out of their true position in clockwise direction when the head is inclined to the right, and in counter-clockwise direction when the head is turned to the left.

At the suggestion of Professor C. E. St. John, some settings were made while the observer lay on a horizontal raised board with head supported so that the line joining the eyes was vertical. In this case the deviations were enormous, as may be seen in the results given in Table III. It will be observed that the apparently horizontal and vertical lines were in all cases turned from their true positions, in clockwise direction if the observer was lying on his right side, and in counter-clockwise direction if he was lying on his left side. If, after a setting had been made, the observer looked away from the instrument and at the walls of the room for a little while and then back again into the telescope, the deviation seemed enormous at first, but it decreased rapidly and continuously, and at the end of, perhaps, ten seconds the setting seemed again good. While making these observations the eyes were carefully screened.

The second piece of apparatus is represented, though without its screen, in the accompanying figure. The observer, looking through a horizontal tube about 35 centimeters in diameter and 2 meters long, which shuts out of sight extraneous objects and is blackened inside and furnished with several diaphragms to prevent reflection from the inner surface, sees a white circular field 35 centimeters in diameter, divided into halves by a fine, straight, black ink line. This field is the central portion of a large piece of smooth cardboard, mounted on a wooden disc, 75 centimeters in diameter. The disc is in a vertical plane perpendicular to the line of sight, and can be turned about a horizontal axis in the geometrical axis (produced) of the observing tube. By the use of simple mechanism the observer may rotate the disc until the line on the cardboard seems to him horizontal or vertical. Its deviation from true horizontality or verticality can then be read off, to a hundredth of a degree if such accuracy is ever desirable, by an assistant with the help of a microscope and scale on the back of the disc.

While using this apparatus the observer can stand on a platform of proper height, level or inclined, or he may sit on a high chair. In any case his eyes must be properly screened* so that he cannot see any outside objects. The apparatus is furnished with a large metal screen not shown in the illustration.

TABLE III.

Observer.	Mean of horizontal settings made while lying on the				Mean of vertical settings made while lying on the			
	left side,		right side,		left side,		right side,	
	by the left eye.	by therig eye.	bythe ; eye.	by the right eye.	by the left eye.	by the right eye.	by the left eye.	by the right eye.
1	—16°	——	——	+ 9°	—14°	——	——	+20°
4	—10	—11°	+10°	+ 6	— 6	—13°	+ 7°	+ 4
5	—11	——	——	+15	— 7	——	——	+18
8	—22	—13	+11	+17	—22	—15	+19	+14

The observers were those denoted by the same numbers in Table I.

* In some experiments made recently in the laboratory of Professor Cattell, of Columbia University, the observer was wisely stationed in a perfectly dark room.

Table IV.

Observer.	Horizontal Settings. (The readings show deviations from level.)					Vertical Settings. (The readings show deviations from verticality.)				
	The mean of the set of readings.	The algebraically smallest reading.	The algebraically largest reading.	The "range" of the readings.	The average deviation of the readings from their mean.	The mean of the set of readings.	The algebraically smallest reading.	The algebraically largest reading.	The "range" of the readings.	The average deviation of the readings from their mean.
1	—1°.19	—1°.48	—0°.85	0°.63	0°.21	—1°.02	—1°.39	—0°.55	0°.84	0°.21
2	—0 .16	—1 .00	+0 .62	1 .62	0 .32	—0 .03	—0 .98	+0 .64	1 .62	0 .36
3	—0 .44	—1 .10	+0 .32	1 .42	0 .32	—0 .55	—1 .70	+0 .28	1 .98	0 .33
4	—0 .10	—1 .41	+1 .10	2 .51	0 .48	—1 .59	—3 .10	—0 .50	2 .60	0 .62
5	+0 .26	—0 .53	+1 .07	1 .60	0 .33	+1 .29	+0 .42	+2 .36	1 .94	0 .42
6	—1 .22	+2 .13	—0 .50	1 .63	0 .32	—0 .59	—1 .37	+0 .05	1 .42	0 .29
7	—0 .44	—0 .90	—0 .02	0 .88	0 .25	—0 .46	—1 .56	+0 .42	1 .98	0 .44
8	—0 .81	—1 .50	—0 .30	1 .20	0 .24	—0 .30	—0 .70	+0 .06	0 .76	0 .20
9	—0 .38	—1 .12	+0 .04	1 .16	0 .24	+0 .42	—0 .26	+1 .08	1 .34	0 .32
10	±0 .00	—0 .72	+0 .60	1 .32	0 .26	+0 .08	—0 .70	+0 .95	1 .65	0 .53
11	+0 .56	—0 .45	+1 .40	1 .95	0 .33	—0 .33	—1 .08	+0 .38	1 .46	0 .36
12	—0 .11	—1 .00	+0 .55	1 .55	0 .37	—0 .10	—0 .83	+0 .67	1 .50	0 .25
13	—0 .23	—1 .30	+0 .57	1 .87	0 .39	—0 .10	—1 .07	+0 .83	1 .90	0 .44
14	—0 .01	—0 .64	+0 .57	1 .21	0 .24	+0 .50	—0 .17	+1 .48	1 .65	0 .34
15	+0 .01	—0 .76	+0 .65	1 .41	0 .27	—0 .09	—1 .25	+0 .70	1 .95	0 .38
16	+0 .17	—2 .03	+2 .02	4 .05	0 .01	—1 .41	—2 .89	+1 .62	4 .51	0 .67
17	+0 .42	—0 .11	+0 .92	1 .03	0 .23	+0 .77	—0 .17	+1 .61	1 .78	0 .37
18	+0 .81	+0 .35	+1 .52	1 .17	0 .27	—0 .05	—0 .65	+1 .30	1 .95	0 .50
19	+0 .28	—0 .98	+1 .82	2 .80	0 .69	—0 .32	—1 .78	+0 .77	2 .55	0 .49
20	—0 .16	—0 .80	+0 .80	1 .60	0 .27	+0 .64	+0 .01	+1 .48	1 .47	0 .41
21	+0 .18	—0 .62	+0 .85	1 .47	0 .29	+0 .01	—0 .77	+0 .76	1 .53	0 .26
22	—0 .04	—0 .64	+0 .43	1 .07	0 .17	+0 .02	—0 .30	+0 .44	0 .74	0 .18
23	+0 .19	—0 .60	+0 .86	1 .46	0 .33	+0 .33	—0 .62	+1 .15	1 .77	0 .49
24	+0 .04	—1 .43	+1 .60	3 .03	0 .65	—0 .67	—2 .27	+1 .44	3 .71	0 .67
25	—0 .86	—3 .71	+1 .87	5 .58	1 .39	—0 .81	—4 .01	+4 .05	8 .09	0 .75
26	—0 .45	—2 .52	+1 .81	4 .33	0 .71	—1 .55	—3 .40	—0 .37	3 .03	0 .61
27	+1 .16	+0 .65	+1 .56	0 .91	0 .16	+0 .97	+0 .68	+1 .35	0 .67	0 .13
28	+0 .39	+0 .01	+0 .79	0 .78	0 .20	—0 .07	—0 .52	+0 .35	0 .87	0 .16
29	—0 .38	—1 .60	+0 .50	2 .10	0 .58	—0 .59	—1 .19	+0 .20	1 .39	0 .36

With this apparatus many hundreds of settings were made. Table IV. contains the results of a large number of these made by 29 different persons, each one of whom, while making his long set of observations, stood at ease in front of the tube and, using both eyes, attempted to set the line correctly. All the angles are here given, as they were first read, to hundredths of a degree, but it is evident that the last figure is generally nearly meaningless. Of these 29 persons, two (Nos. 25 and 26) are boys 10 and 8 years old, respectively, and No. 16 is a somewhat older boy. Nos. 23 and 24 are young girls. The ranges of four of these five children are noticeably large. No. 21 is a lady. Thirteen of the other observers, all of whom are men, are either instructors in Harvard University, or other members of the staff of the Jefferson Physical Laboratory. It should be said that a given number may represent different observers in the different tables.

Eleven of the twenty-nine subjects were known to be astigmatic. Most of these could see very imperfectly without eyeglasses, and yet they could set the line about as accurately without these glasses as with them. For instance, the means of horizontal and vertical settings made by observer No. 13 without his spectacles, were — 0°.20 and + 0°.02 respectively. There does not seem to be any obvious connection between the directions of the principal axis of the eyes of an astigmatic observer and the bias shown by his observations.

The average range of the 24 adult persons represented in the Table is 1°.45 for horizontal settings and 1°.56 for vertical settings. The corresponding ranges of so many of these persons as were distinctly astigmatic were 1°.48 and 1°.56 respectively. The average deviation of the horizontal settings of the astigmatic adults is 0°.46 and of the other adults 0°.35. The corresponding average deviations of the vertical settings were 0°.32 and 0°.54. I have partial records for a good many other persons but the numbers given in the Table are fairly representative.

Taking into account all the results, and calling the mean of a great number of readings of settings made by any person, his 'deviation,' we may say, that persons entirely untrained in making measurements, generally set the line rather carelessly, as children do, and have large ranges, though their deviations are not especially large. Trained observers have smaller ranges than other people, but their deviations are not noticeably small. Astigmatism, so severe as to require the constant use of spectacles, does not seem to affect the readings much. Only one person in ten is likely to have a deviation as great as 1° for horizontal settings, while one person in five may be expected to have a deviation of 1° or more for vertical settings. A deviation as great as 1°.6 is very unusual, but many persons may be found whose deviations both from horizontality and verticality are less than 0°.1. The average deviation is about 0°.4 for horizontal settings, and about 0°.5 for vertical settings.

If the platform upon which the observer stands be inclined (sidewise) to the horizon, he becomes ill at ease and his deviations are generally altered. Whether the platform is tipped downward towards the left or towards the right, however, seems in many cases not to affect the signs of the new deviations, which are sometimes, if not usually, mere exaggerations of those obtained when the platform is level. A certain skillful mechanician, for instance, had deviations from horizontality and verticality of + 0°.5 and — 0°.8, respectively, with platform inclined 5° downward to the right, and corresponding deviations of +0°.6 and — 0°.6 with platform inclined to the left. His horizontal and vertical deviations when the platform was level, were positive and negative respectively, but not greater than 0°.1 in either case.

If the observer stood on a level platform, squarely facing in a direction at right angles to the axis of the tube, and then looked over his shoulder, using both eyes and turning only the head and neck, he was still able to set the line horizontal or vertical with some accuracy. The horizontal deviations of two observers while standing in the way just described and looking over their right shoulders were ± 0°.0 and — 1°.0. Their vertical deviations were — 0°.2 and — 1°.0.

Table V. gives the results of some settings taken when the observer, using only one eye, stood at his ease in front of his instrument.

TABLE V.

Observer.	Means of horizontal settings made with			Means of vertical settings made with		
	the right eye.	the left eye.	both eyes	the left eye.	the right eye.	both eyes.
1	—0°.4	—0°.1	±0°.0	±0°.0	—0°.1	±0°.0
2	+1 .4	—0 .7	+1 .4	+1 .3	+0 .2	+0 .8
3	+0 .1	+0 .8	±0 .0	—0 .4	±0 .0	+0 .1

It should be said that the first two of th ese observers when asked to point quickly at a distant object, always indicate a line passing midway between the eyes, and not a line passing through one eye, as many people do.

Two persons successively took observations by standing on a shelf with back squarely turned to the tube and trying to set the line horizontal while looking backwards between the legs with head inverted.

The deviation of one of these persons was $-1°.4$. The settings of the other were always positive when made from the positive side and negative when made from the negative side. The average deviation of a single setting made by this person was in absolute amount $1°.5$.

When settings are made by a person while standing squarely before the instrument with his head *much* inclined to one side, the deviations are always clockwise when the inclination is to the right, and counter-clockwise when the inclination is to the left. When the inclination is small it is, of course, not possible to predict the signs of the deviations. The settings of one observer, and of only one among several who were examined, were exceptions to the rule when the head was inclined as much as 20°. In Table VI. the first line gives the deviations of an observer fairly representative of the average, and the second line those of the exceptional person just mentioned. The inclinations were very nearly 20° in all cases.

TABLE VI.

Observer.	Horizontal settings made, when the head was inclined to the						Vertical settings made when the head was inclined to the					
	Left,			Right,			Left,			Right,		
	using the left eye.	using the right eye.	using both eyes.	using the left eye.	using the right eye.	using both eyes.	using the left eye.	using the right eye.	using both eyes.	using the left eye.	using the right eye.	using both eyes.
1	$-2°.3$	$-0°.9$	$-2°.0$	$+2°.1$	$+1°.4$	$+1°.9$	$-1°.9$	$-2°.2$	$-1°.9$	$+0°.7$	$+1°.5$	$+1°.4$
2	$+1\ .3$	$+3\ .4$	$+2\ .1$	$-0\ .6$	$+0\ .9$	$+1\ .4$	$+1\ .1$	$+2\ .2$	$+1\ .2$	$-0\ .6$	$-1\ .0$	$-2\ .4$

When the observer lay on one side on a horizontal shelf, with the line joining his eyes vertical, and with head well screened for some time before he made his settings, the deviations were in all cases clockwise if he lay on his right side and counter-clockwise if he lay on his left side, whether he used one eye or both. The magnitudes of the deviations, though very different with different people, were often as great as 20°.

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THE DEVONIAN SYSTEM IN CANADA.

II.

2. ONTARIO AND KEEWATIN (HUDSON BAY).

While Logan was exploring the Gaspé sandstones in 1843, Mr. A. Murray, then Assistant Geologist to the Canadian Survey, was engaged in a "geological examination of the district lying in a general line between Georgian Bay, on Lake Huron, and the lower extremity of Lake Erie." In his report on that year's operations, published in 1845, Mr. Murray correctly, and for the first time, regards the rocks at Port Colborne, Cayuga, etc., which he calls the Upper Limestones, as the equivalents of the Corniferous limestone of the State of New York. The black bituminous shales at Kettle Point, Lake Huron and on the Sydenham River, that he examined in 1848, he at first thought to be part of the Hamilton formation, but in 1855 he re-examined these shales and some of the exposures on the Sable River and in the township of Bosanquet, in company with James Hall, upon whose authority the former were decided to represent the lowest member of the Portage and Chemung group and the latter the Hamilton formation. But this statement was not published until 1857.

The discovery of the Oriskany sandstone at Cayuga would seem to have been made, or rather first recorded, by E. Billings, in May, 1860. For, in the preface to his now classical paper 'On the Devonian Fossils of Canada West,' Mr. Billings says that the "Devonian rocks of Canada West consist of portions of the Oriskany sandstone,